THE

AËRONAUTICAL JOURNAL

(Founded 1897 in succession to the Annual Reports).

The Organ of the Aëronautical Society of Great Britain.

Published Monthly at the Offices of the Society, at 7, Albemarle Street, Piccadilly, London, W.1.
Telephone: "Gerrard 7373." Telegraphic Address: "Didaskalos, Piccy, London."
Subscriptions per annum, post free, £1 10s.; single numbers, 2s. 6d.

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All communications should be addressed to the Editor.

No. 86. FEBRUARY, 1918. Vol. XXII.

Notices of the Aëronautical Society of Great Britain.

Obituary.

The Council record with great regret the death of Colonel Sir John Wolfe Barry, K.C.B., LL.D., F.R.S., D.L., who joined the Society in 1917; of Engineer Commander W. B. Hall, who joined the Society in 1909; and of Prob. Flight Officer E. H. Dyson, who joined in 1917.

New Members.

Fellows.—Charles Bright, M.Inst.C.E., F.R.S.E., R. Borlase Matthews, A.M.Inst.C.E. (2).

Associate Fellows.—H. A. Smith, A. F. Arcier, M. A. Feary, F. A. Cobb, A. W. Pearce, A. N. Kingsbury, W. M. Bernard Murphy (7).

Members.—S. J. Waring, J. Marsh, L. G. Savage, E. C. P. Allardyce (4).

Associate Members.—R. B. North, S. Camm, F. S. Clare, C. W. Fishenden, C. L. Archbold, Major T. G. Clarson, A. R. Parbridge, F. G. Smith, J. M. Freedman, M. G. Lee, A. G. Brayshaw, H. B. Browne (12).

Students.—G. Lockley, R. H. Dobson, F. A. Wilkinson, A. B. Miller, H. R. Polden, R. Inns, R. Rodger (7).

Errata.

In the appendix to Captain F. M. Green's paper on "The Technical History of the Aeroplane" (p. 12, ninth and tenth lines from bottom of page) "minimum" should read "maximum."

In the January number of the Journal a notice was inserted of the death of Captain A. Graham Clarke, of the M.A. Directorate. This information reached the Journal from official sources. We are happy to state that it was incorrect and hasten to offer our apologies to Captain Clarke and his friends.

Recent Additions to the Library.

"Water Vapour Transparency to Low Temperature Radiation." F. E. Fowle. Smithsonian Institution, October 27th, 1917.

"Effect of Short Period Variations of Solar Radiation on the Earth's Atmosphere." (With eight charts.) H. Helm Clayton, Argentine Meteorological Service, Buenos Aires. Smithsonian Institution, May, 1917.

"Notes on Pyrometry from the Standpoint of Ferrous Metallurgy." Dr. W. H. Hatfield (Sheffield). From the transactions of the Faraday Society.

Note.

The following horse-power formula for modern aero engines was suggested by Mr. Dendy Marshall in the course of the discussion on Mr. Coatalen's paper on "Aero Engines," read before the Aëronautical Society on May 16th last, but was accidentally omitted from the printed report.

Where d is diameter,

s is stroke,
n is number of cylinders,
r is revolutions per minute,

$$\frac{d^2snr}{7{,}500} \text{ when dimensions are in inches,}$$

$$\frac{d^2snr}{123{,}000{,}000} \text{ when dimensions are in millimetres.}$$

This corresponds to 20.7 h.p. per litre at 2,000 revs., and an m.e.p. of 134.5 lbs. per square inch. Mr. Coatalen gave 18 to 21 h.p. per litre, considering the latter figure likely to be the maximum for the present designs of engines.

Educational Lectures.

The courses of lectures given at Southampton, Farnborough, Birmingham, Bristol, and Hammersmith, are now completed or nearing completion. The courses at Hendon, Peterborough, Norwich, Coventry, Leeds, and Lincoln have been successfully launched. So far we have to record an average attendance at all these places of something like 600 per lecture, so that the scheme has more than justified the hopes with which it was begun. It now only remains to carry on the work another year and it is to be hoped that means will be found by which this can be done. An admirable result would be the establishment of "student" or "graduate" branches of the Society in all the centres of the aircraft industry mentioned. We hope that this will be done. Perhaps those interested in the formation of "graduate" branches will consider the matter.

THE USE OF JIGS IN AEROPLANE MANUFACTURE.

BY R. BORLASE MATTHEWS, WH. EX., A.M.I.C.E., M.I.E.E., F.AË.S.

Introductory.

A new industry calls for new methods—*autres jours, autres mœurs*—and the aeroplane industry is therefore not exceptional in demanding many departures from recognised woodworking practice. In the first place the number of machines required to-day is so large that their construction should be described as a manufacturing rather than a building operation. That is to say, they should preferably be almost entirely put together by the aid of accurate machinery instead of being dependent to such an extent upon the skill of the individual workman, in trying and fitting one part to another until the whole is built up. In this connection it may be remarked that the design of the metal fittings for aeroplanes is not such as to call for any radical departure from previous high class small metal working practice. It is the woodworking side of the business which presents the new scope for initiative. It is this latter aspect, therefore, which will be considered here.

The underlying ideal of the modernised system now advocated, is, that the arrangement of the work and the facilities for economically carrying it out should be planned and designed in the office as distinct from the shops where the actual work is done. For a great number of years it has been realised in engineering establishments that drawings are essential and economical, likewise sooner or later it will be appreciated that drawings of jigs and fixtures are just as necessary.

It may be mentioned in passing, that since the subject is treated as a whole, all the points raised, would obviously not necessarily be applied to the manufacture of one particular type of machine, as so much depends upon circumstances, the size of the order, the probabilities of modifications in design during progress, etc.

Definition of Jigs and Fixtures.

The distinction between a jig and a fixture is not an easy one to define, as it is difficult to say where one ends and the other begins. A jig is a device which either holds, or is held on to the work, and at the same time incorporates guides for the various cutting tools; whereas a fixture holds the work while the cutting tools are in operation, but does not contain any special arrangements for guiding the cutting tools. In other words, a fixture is usually a device which must be entirely held or fixed to the machine on which the operation is performed. The term fixture is often, however, also applied to assembling arrangements of larger size, which form complete units in themselves and are generally permanently attached to concrete foundations. Gauges must, of course, not be confounded with jigs.

A Comparison between Engine and Aeroplane Manufacture.

In manufacturing engines in quantities it has long been the practice to use jigs and fixtures in order to speed up production and also to ensure correctness of output. But up to the present, in aeroplane manufacture, this practice has not been adopted to such an extent as it might have been, with the result that it takes very much longer to turn out an aeroplane than is necessary. This delay arises, both in production of detail parts and also in the assembly of units and complete

machines. Considerable time is lost throughout, in trying and fitting the parts into their correct relation, owing to errors in making the details.

For example, assume that in an engine two parts are required to be bolted together. These parts are not clamped together and then drilled both at the same time, nor is one part drilled and the other clamped up to it and drilled through the first. Both parts are drilled separately in jigs. This may be done in a separate department, or even in a separate factory, and still the parts will bolt together in their correct relation.

But in the majority of aeroplane works quite a different state of affairs exists. Take, for example, the case of spars which have to have metal brackets attached to clamp up to other parts. Here the metal parts are placed over the spars when they have been put in position relative to other parts. The spar is then drilled through holes already drilled in the metal parts. This entails much difficulty, because the job is inaccessible; it also promotes inaccuracy, owing to the operator having to drill from both sides to ensure that there will be a clear way for the bolts through both sides. All this troublesome work and subsequent delay would be avoided were the spars and metal parts drilled in jigs. All that would then be necessary would be to push through the bolts and tighten up.

Again, take the spindling of spars. For the sake of comparison, the milling of straight metal parts may be considered, when the work travels on a horizontal table against the cutter. Here the length to be machined is controlled by stops. In the spindling of spars the job should be placed in a jig having stops upon it, so that it is impossible for the cutter to operate except where it is so desired. By proper design of the jig, the cut out portions will come in correct relation to the overall length and depth.

In cutting form or taper shapes, as, for example, the nose pieces on rotary engines, forming plates are used to compel the tool and the work to move in such a manner that the desired finished form is arrived at. This principle might well be adopted in woodworking, when parts have to be spindled to some special form or taper. The jig would be made with a "former" for bearing against the spindle, which will only allow the cutter to operate in such a way as to produce the desired shape.

The "former" idea should be extended to cover work on the band saw, either for roughing to shape or for finished work when the saw finish is good enough.

For the use of such "forming" jigs on spindling machines, the "former" should bear against a ball bearing embracing the spindle. This will very much reduce the wear on the "former" and so ensure a much longer life for the jig as regards accuracy.

Of course, these "formers" entirely do away with the necessity for marking out shapes, entailing, as the latter operation does, a great amount of time.

The various units that go to make up a complete machine should be assembled in a jig. The jig should hold each unit by at least two locating points. The units, when held in the jig, will all come into their correct relative positions. All that will then have to be done will be to bolt up, through holes drilled in the jigs used for making the parts.

Careful consideration as to the cost of production must be given before setting about the design of a jig or fixture, as obviously it is absurd if the cost of the jig is in excess of the anticipated gain. The only exception that would permit of the employment of a jig, which did not comply with the above conditions, is where accuracy of parts is of such importance as to make interchangeability of these parts absolutely essential.

Time and Cost Saved by Use of Jigs.

As an illustration of time saving, many aeroplanes could be made in three-fifths of the present time required, if proper jigs and fixtures were in existence. The cost would be reduced by something like twenty-five per cent., this estimate being based upon a small number of machines, say 250. On a larger number, say 1,000, the saving in labour would be about fifty per cent., and naturally the saving in labour means increased speed in production.

As a detail example of economy the elevator of a certain machine used to cost in labour alone £2 10s. 0d.; this was immediately reduced to under a sovereign on the introduction of proper jigs. Many other similar cases could be cited.

Jig and Fixture Drawings.

A modern aeroplane requires at least 1,200 jigs and fixtures. It is obvious that to make so large a number with accuracy, and to ensure that the right number are ordered, these jigs should be made to drawings. At present the comparatively few jigs that are employed are, as a rule, made to the shop foreman's more or less crude ideas. It therefore follows, that when some machine or parts of machines are made by more than one sub-contractor, there will, assuming all sub-contractors work to jigs, be as many different types or styles of jigs to do the same job. Each of these different jigs, to do the same job, is the result of separate thought.

Here, obviously, is an opportunity for economising time, for if the jig had been properly designed in a drawing office, all that would have been necessary would have been to have sent a copy of the jig drawing to all sub-contractors, who would then have made their jigs without wasting time in thought and consideration.

The Need of Organised Design.

In accordance with well tried principles, sometimes known in the aggregate as Taylorism (out of compliment to the original investigator), it is clear that if work is to be carried out according to scientific laws, the management must be so organised as to execute itself much of the planning formerly left to the initiative of the individual workman. The older method of works management has been described as that of "initiative and incentive," the underlying philosophy of which necessarily leaves the detail solution of daily problems to the man at the bench. The incentive offered in this way, in return for initiative, is merely monetary reward. The method is faulty, because the workman's whole time should be actually taken in doing work with his hands. Even if he had the necessary education and habits of generalisation in his thought, he lacks the time and the opportunity for the development of the underlying scientific principles, and without these much effort can be frittered away. Again, any actual development of applications by an individual worker is not easily disseminated amongst others. Under scientific management exact scientific knowledge and methods must earlier or later replace rule-of-thumb ways everywhere. It may be fairly stated that the days have passed when an individual man of strong personality can do big things without the assistance of others. Rather, the present age is one of co-operative specialisation, in which all great achievements are accomplished, and will continue to be, by that type of co-operation in which each man performs the function for which he is best suited, preserving fully his own individuality, and losing none of his originality and proper personal initiative. At the same time, however, he must be controlled by and must work harmoniously with his fellow men.

The Application of Organised Design.

The application of scientific principles is naturally just as important in aeroplane manufacture as in any other branch of industry. It has its own special difficulties, but that is all the more reason that steps should be taken to effectively combat them. One of the strongest arguments brought forward against the adoption of a well developed jigging system for aeroplane construction, is that in the present stage of the art, developments are so rapid and so many modifications have to be introduced in the machines that it is impossible to evolve a reasonable system of manufacture. The reply to this is, of course, that the design details of the jigging system must be so elastic as to permit of the introduction of modifications without delaying the progress of work. This only means that all the greater forethought and intelligence must be exercised, and further emphasises the fact that aeroplane designs must be prepared by practical specialists. From the foregoing remarks it will be gathered that aeroplane jig designs cannot always be as simple as might be desired, since the jigs must be so constructed as to be readily and quickly altered, with a minimum expenditure of time and material, to conform to any required modifications. After all, the general run of modification only affects minor details as a rule, hence the modification bugbear is not so serious a matter as it might appear to be at the first encounter, especially as only too many alterations are merely made to facilitate manufacture.

The existence of a jig and fixture drawing office would constitute a most valuable check upon the drawings, and would prevent many of the mistakes which have gone through to the shops in the past. This, in itself, would almost be worth the small extra staff and expense.

It has been estimated that during the life of many aeroplanes something like 400 modifications have to be incorporated, most of which are to correct drawing office errors and to overcome manufacturing troubles. A very considerable portion of these would be eliminated, if jigs and fixtures were designed concurrently with the working drawings of the machines. As regards the elimination of manufacturing difficulties it might be mentioned that one particular aeroplane could be manufactured in one-third the time it now takes, if only the mechanical details were more united to manufacturing processes.

The obvious moral of the foregoing is that jigs and fixtures should be designed by a drawing office fully conversant with the whole design of the machine, including engine fittings and the fitting of the various instruments. To post all the shops and sub-contractors with this mass of information would obviously take a tremendous lot of time. Therefore it is clear that all the jigs for a machine should be designed by one drawing office and drawings and instructions distributed to the various shops and sub-contractors.

This centralising of jig design has the great advantage, besides time saved in actual design, that all manufacturers will be posted as to the best way to make machines, having due regard to speed of production and soundness of job.

Another strong reason for a jig designing department is that the smaller aeroplane manufacturers, as a whole, are not mechanical engineers, and have had no experience upon which to fall back in designing jigs. In fact, many of them fail to appreciate that any speeding up of output could be attained by the extended use of jigs. This is due to the fact that in their experience, previous work of a different nature, they did not feel the need of such aids, as their work was more varied.

Classification of Jigs and Fixtures.

It has already been mentioned that at least 1,200 jigs and fixtures are necessary for the manufacture of a modern aeroplane. In fact (including jigs for metal fittings) one maker employs 5,000 to great advantage. Hence, it will be of interest to consider the classification of a modern equipment.

1. Parts Jigs.

(*a*) *Mill Jigs.*—For sawing, spindling, etc., parts to their exact size.

(*b*) *Drilling Jigs.*—For drilling all the holes called for on the fittings, the necessary bolt holes and the entering holes for large wood screws.

(*c*) *Parts Jigs.*—For completing the small built up parts, ready for attachment to components.

2. Component Jigs.

(*a*) *Building Jigs.*—For assembling the various parts into a component (such as ribs, ammunition carriers, etc.).

(*b*) *Taping and Varnishing Jigs.*—For assisting in the quick winding of tape where necessary and for presenting the component in the best possible way for doping and varnishing. These jigs usually take the form of two centre points on which the work rotates.

3. Unit Jigs and Fixtures.

(*a*) *Unit Assembly Jigs.*—For assembling parts and components into a unit (such as wings, fuselages, ailerons, tail planes, etc.). These should locate the exact position for each part; and the parts, if made correctly, need not be touched by hand, the only work necessary being the insertion of necessary bolts, screws, etc., and wiring.

(*b*) *Unit Fixtures.*—Take the form of benches specially made for a certain process, such as covering with fabric, doping, etc., designed to facilitate rapid handling of the unit in construction.

4. Erection Fixtures.

Are constructed to facilitate assembly of the units to the complete machine. A cradle should take the fuselage in its correct position, giving access for affixing the undercarriage, the tail skid, and the planes. A supplementary fixture gives the exact position of the wings at the tips and fuselage, and obviates the difficulty of correctly pitching the dihedral, using plumb lines, etc. A tension gauge or tautometer should be used to determine the tautness of wiring, and by careful application a much better rigging will be ensured than is secured by the old method of straining until the correct alignment is secured.

The Principles of Design of Jigs and Fixtures.

The general principles that must be followed out in laying out a jig or fixture is to decide upon the locating points of the outline of the clamping or holding arrangements. It should be borne in mind that these latter devices must be as quick acting as possible, and for rough work (*i.e.*, the early operations) some of the locating points will have to be made adjustable. Each jig should be so arranged that the work can only be inserted in the correct way. The ideal method of arranging the clamping and fixing devices is by placing them in the best position to resist the pressure of the cutting tools, that is, all clamps and fixing devices should be integral parts. At the same time complication must be avoided, as one of the objects of a good jig is to eliminate highly skilled labour. Effective support must be provided opposite to surfaces that contain guide bushings. If possible the jig should be so designed that all the locating points are visible to the operator when placing the work in position. Suitable clearance must be provided for the escape of cuttings and chips. Auxiliary devices that facilitate the manipu-

lation of the jig, such as handles, should be provided whenever they assist in shortening the time required.

Many works claim to have very good jig equipments. Unfortunately, however, when the matter is probed into by anyone who really knows the full application of this method of manufacture, the reverse is only too often found to be the case. The usual much-lauded jig equipment generally only comprises a comparatively small number (*i.e.*, in regard to the 1,200 or so previously mentioned as necessary) of so-called board jigs. These consist of flat boards fitted with positioning stops and cam clamps. There is perhaps no more simple and useful all round type of jig than this, and it is very widely used in many most ingenious modifications. Unfortunately, however, it is often incorrectly employed, being used as a gauging jig rather than an assembling device. That is to say, a carpenter's bench is placed alongside, and strips of ready planed wood are tried out to length and fitted in place by the handicraft of the workman. In good modern jig practice, hand tools are entirely prohibited. The reason for this is that all parts, however small, should be made in their own particular jigs. If at any time it is discovered that a part does not fit correctly into its proper place, hand tools must not be used to correct the deficiency, but rather the fault which caused the defect must be eliminated from the worn or incorrect jig originally used to make that part.

A description of the whole art of the design of jigs and fixtures would require a voluminous treatise. As neither space nor time will permit of such full treatment here, it is proposed to summarise in the form of a running commentary a few of the main points that are often overlooked.

Saw Mill Jigs.

A great deal of subsequent work can be saved if the preliminary rough sawing is done to close limits of the finished sizes. This can be accomplished by means of suitable jigs, which can be clamped on to the timber and serve as guides. During sawing, the guiding portions would be kept by the sawyer in contact with fences on the saw bench.

Spindling Machines.

With the aid of carefully thought out jigs, these machines are invaluable to an aeroplane manufacturer. At the present time they are not utilised to anything like the extent to which they should be for lack of jigs. Preferably suitable ball races should be fixed on the projecting portions of the spindles for the jigs to bear against and thus reduce jig wear to a minimum. As far as is feasible safety tool holders should be employed, for not only are they a protection to the operator, but they also facilitate the setting of the tool and the cutting edge is more easily arranged at the best cutting angle.

No hand tool work should be permitted in an aeroplane factory. Hence, all parts, even the smallest, should be made on spindling machines of some kind. With the aid of proper jigs it is really wonderful what work can be done in this direction. For light work it is not essential to employ the heavy standard spindling machines, as some manufacturers have successfully employed short ball bearing shafts, which have been fixed in a vertical position on stout wood framework.

Jigs for small parts should be so constructed that several pieces may be spindled at the same time; if the clamping arrangements are adequate the several pieces will lie flat and the finished shapes will be identical.

Colour Scheme.

These various small pieces should be stored in separate boxes or bins. All the boxes or bins containing the pieces for one particular component should be painted a distinctive colour or combination of colours. The jig in which these parts are assembled should be painted the same colour or combination of colours. This materially assists the operatives, and is a scheme which might be standardised throughout the country.

Tools and Gauges.

All special form cutters should be made to designs prepared in the jig and fixture drawing office. This will ensure all sub-contractors turning out identical parts. The tools should be set in the various machines to gauges and not to pattern parts. These gauges should be designed in the drawing office. Then all sub-contractors would have to set their tools to perform exactly the same work and incidentally save considerable time.

All cutters and gauges should be made in quantities in a tool-room, similar to an engineering works tool-room. An operator should not be allowed to do anything to a tool more than just to stone it up in position. The tools should be set in the spindle to a gauge and not to a pattern part. By this means any number of sub-contractors will be in a better position to produce identical parts.

All tools and gauges should be made to special drawings and not according to the operator's ideas in the various shops. Thus, a complete record is kept of how to do a job, and it is an easy thing to start a new workman in the way he should go.

If proper use is made of jigs, tools and gauges, it will be impossible to turn out work that is not correct, although the worker may have no experience of aeroplane work at all.

Special Tool Steels.

It is put forward that undoubtedly superior steels should be employed for wood working than those now utilised. This would permit of the machine tools operating at higher speeds than they do at present, which would result both in a bigger output and better work. Machines which now run at 5,000 revolutions per minute could be speeded up to something like 7,000 revolutions per minute. It is true that this would shorten the life of each machine, but much better and quicker work would be done.

Special Shop to Make Jigs, Tools and Gauges.

It is suggested that since most aeroplane sub-contractors have no tool-room facilities, a special jig and tool shop should be run in connection with the drawing office to manufacture all tools, jigs, etc., which sub-contractors are not in a position to make for themselves. Then tools and gauges could be turned out in quantities and sub-contractors would be assured of a good supply to assist them in their efforts to attain maximum production.

Much could certainly be learned from metal milling practice that could advantageously be applied to the operation of spindling machines. In fact, inverted spindle machines with face cutters are already in use. Horizontal spindles could also undoubtedly be employed with advantage.

Drilling Jigs.

Much greater accuracy could be secured by making the guide bushes for the drills of proper length, relative to the size of the drill. At present many drilling

jigs do little more than serve to indicate the position of the holes—there is insufficient bearing to take care of the truth of the drilling.

Limits.

As in the case of metal working, absolute accuracy in wood-working is not only impossible, but also unnecessary. Hence, maximum and minimum limits are required for all dimensions in aeroplane work. These limits are naturally much wider than those essential for metal work. For both holes they are usually of the order of plus or minus 0.01 inch. For lengths of under three feet the allowance is normally plus or minus 0.03 inch; for longer pieces the allowance is increased 0.01 per foot; due discretion being exercised according to the circumstances, *e.g.*, on aileron hinge joints of, say, eight feet or so, it would not be more than 0.04 to 0.05 inch, with present day designs. However, hinge design is a matter that should receive more attention. There is a tendency for spars to warp across the grain if exposed to bad weather conditions, hence a limit of 0.05 inch is usually provided to counteract these atmospheric effects.

When seasoned wood has been milled it should be laid aside for about ten days and then drilled by jig before the fittings are assembled. It will then be found that no trouble will be experienced when the parts are fitted together, as there will be no appreciable shrinkage under these conditions.

Board Jigs.

Small pieces are generally put together to form components on a board jig. This consists of a board on which small positioned pieces of wood (or in some cases metal) and locking turn buttons are fixed in such a way that a piece of wood placed round the outside or inside will assume the required curve. If these boards were built up on some sort of box frame, or series of small boxes, and the ordinate length stops fixed to sliding pieces, these boards could be turned out in quantities and merely adjusted to the various ribs. This would save considerable time in setting up the board and when a particular rib was finished the board would not be scrap, but could be readjusted to fresh parts.

In the case of board jigs for holding pieces together when glued, the curve must be cut from a board so as to give contact along the whole outside member. Clamping cams, or turn buttons, for board jigs, should be standardised and turned out in quantities so that they can be supplied from stock. These cams should be designed so that they will give a grip that is not too sudden. One of the best designs is that of an eccentric "comma."

Unit Assembly Jigs.

The wings, tail planes, etc., should be fitted together in a jig, so designed, that both sides can be worked on and in such a way that it is impossible to assemble a portion in the wrong manner. For glueing operations a number of similar jigs are often required, so that sufficient time may be allowed for the glue to set, without holding up the workpeople. Glued portions should be clamped together until set. On large assembly jigs the design of suitable clamping devices affords exercise for much ingenuity.

A matter that is often overlooked in aeroplane erection is the necessity for cramping together, under considerable pressure, all members which have been cut across the grain in the process of manufacture. The reason for this is, that however well set the saw may be, it always leaves a soft fibrous mass at the end of a piece of wood when cross cutting it. Heavy pressure will bed the ends of sawn members together. In the case of aeroplanes, which are assembled without proper cramping arrangements, it is found that all the tie wires become slack after one

or two landings. This is undoubtedly due to the giving of the unbedded ends of the various members.

Jigs should be so designed, as a rule, that no operation on them will require more than say two hours' work at a time. Such an arrangement greatly facilitates the passage of work through the shops.

A fixture is in use in several works in which the wings are placed with the correct incidence and dihedral angles. The wires are then strained so that the leading edge assumes such a position relative to a fixed point on the jig that the wing takes up its correct form. The wings are then sent for covering and doping, and it is found that they very seldom require any adjustment when fitting to fuselage. This of course means that wings can be made in quantities and stored, to be withdrawn as required, whether as spares or for fitting to new machines. Some such jigs should be used in the final erection of wings on a machine to ensure that they take up their correct position. To speed up the work a tautness meter may well be used for rapidly testing the straining of the wires.

In one type of fixture, the rear portion of the fuselage is fixed on a sliding table, to have the rudder post fitted dead square and central. There are also guides so that the four front ends of the longerons may be cut off square relatively to the rudder post and to the correct length. The rear portion is then a complete unit, ready to be fixed to the rest of the machine without any further fitting. This is a most desirable fixture and should be used whenever applicable. In the case of large machines the sliding tables should be on the floor level so as to make the job easily accessible.

Erection Fixtures.

The whole machine (not necessarily always including the wings and chassis) should be finally erected in a specially constructed fixture. This usually consists of a large surface plate or a concrete foundation, with brackets fixed so that the various units must come into their correct relative positions. Less reliable forms consist of timber structures.

In Conclusion.

There seems to be no doubt but that for even the building of a small number of aeroplanes, considerable use should be made of both part and component jigs. If the number is in the neighbourhood of 50 or so, the utilisation of quite a number of unit jigs will be advisable, while for anything over 250 machines, jigging can be carried to a considerable extent with great advantage, including more or less elaborate erection fixtures. In fact the only risk in thorough jigging may be said to be in the case of erection fixtures, owing to changes in aeroplane design. However, even these appliances can be designed upon an adjustable basis.

Reference has been made earlier in this paper to the need of organised design along modern scientific lines. Such methods benefit the worker in enabling him to earn higher wages with less strain, while at the same time it is advantageous to the employer. In this consideration a third great party had been overlooked—the whole nation—the consumers, who purchase the product of the first two, and who ultimately pay both the wages of the workpeople and the profit of the employers. A brief scrutiny of industrial history indicates that finally the whole nation gets the greater portion of the benefit coming from industrial improvement. To this end, therefore, any progress in the development and application that may be made in this connection, must be to the ultimate benefit of the people as a whole—even if it appear to be but a side line in industrial work. At the present moment economy in man power is of all importance, therefore anything which can

accelerate the output of such important war material as aeroplanes should be given very careful consideration, even if it involves such a disturbing effort as the direction of thought along unaccustomed lines.

Such then is the case for the more extended application of the use of jigs and fixtures in the manufacture of aeroplanes.

(*The Discussion will be found on page* 61.)

"FLYING IN CLOUDS."

BY SIR HENRY FOWLER, K.B.E.

From Captain Hucks' remarks on the difficulties of keeping a straight course when flying in clouds, and the impossibility of relying upon the compass as a guide when out of sight of a fixed point of reference, it would appear that the nature of the errors to which a compass is liable, and the circumstances under which it may be relied upon are not generally known.

Much work has been done at the Royal Aircraft Factory in the last three years on the behaviour of compasses in the air, and the directions to be followed in their design in order to avoid their errors as far as possible. This work was chiefly done by the late Captain Keith Lucas, F.R.S., who was unfortunately killed when learning to fly, in the autumn of last year. The following is a short statement as to what may be expected from compasses in aeroplanes:—

On account of the dip the N. point of the compass card, when an aeroplane is turning, always tends to point too much towards the centre of the turn, the amount of error varying according to the bearing from which the turn is made.*

When a turn is made in flying towards the N., that is, in any direction N. of E., or N. of W., many compasses will either not indicate the turn at all, or will indicate a turn in the direction opposite to that in which it is actually made.

When flying towards the S., the amount of the turn indicated by the compass is in the right direction, but greater than the turn actually made.

This does not cause great inconvenience when the ground is in sight, or when flying above clouds where the sun or the cloud formation acts as a fixed point of reference by which the turn can be judged, the machine being kept straight on its new course until the compass has settled down.

When flying in clouds which are of uniform texture, so that there is no external object by which to judge the motion of the aeroplane, it is impossible to tell, by reference to external objects, whether the aeroplane is turning, and the only guide is the compass, which in many cases is quite unreliable when steering a northerly course.

For this reason a cloud should, if possible, be entered flying in a southerly direction. The compass then correctly indicates small deviations from a straight course. If it is essential that a course in a northerly direction should be followed, care should be taken to see that on entering a cloud the path of the machine is straight. The compass should then be closely watched, and small indications of the turn should be quickly and lightly checked by the use of the rudder.

With some compasses this will be effective, but with the older pattern of compass the indication is generally incorrect, and it will be impossible to use the compass as a guide. In this case, provided the aeroplane is stable, the best course is to set the aeroplane on its compass course before entering a cloud, then leave it to itself, holding the rudder in the position for flying straight ahead. If the aeroplane is not deflected by bumps this will usually be effective.

Should the air be bumpy the aeroplane will be deflected from its course, and it will continue to climb or glide at the speed for which it is trimmed, and it will

* This statement applies to the Northern Hemisphere. In the Southern Hemisphere the S. point of the card tends to point too much towards the centre of the turn.

keep right side up. If an attempt is made to correct the course it will generally be noticed that the weight on the seat becomes larger, which indicates that a turn is being made. The compass, however, may not show a correction of the course at all, or may indicate a turn in the opposite direction, so that the pilot's sense of direction is completely lost. If the machine gets into difficulties in this way, the best course is, on a stable aeroplane, to leave the controls completely, throttle down, and trim for gliding at a normal speed. The aeroplane will then take care of itself, and will ultimately emerge beneath the clouds when control can be taken again.

In the flights made at the R.A.F., it has been found possible to steer a northerly course without deviation by the use of the compass designed by the late Captain Keith Lucas, the compass only being used as a guide, any small deviations indicated by the compass being quickly corrected.

THE NOMENCLATURE AND NOTATION OF AEROPLANE RIGID DYNAMICS.

BY PROF. G. H. BRYAN, D.SC., F.R.S., FELLOW.

(*Publication of this matter is reserved to this journal.*)

In applying the methods of rigid dynamics of three dimensions to the study of aeroplane motions, one of the first questions which had to be settled by myself and Mr. Harper in the preparation of "Stability in Aviation" was the choice of co-ordinate axes and the notation to be adopted for the various forces, couples and rates of variation of components of air resistance. Where, as in this case, the necessary symbols more than exhaust the ordinary alphabet, the problem is a difficult one, and it was therefore intended to insert a separate section explaining the advantages which rendered the choice adopted the only logically possible one.

Unfortunately, at the time when "Stability in Aviation" was published, very great doubts existed as to the practical utility of any such investigation except as a subject of academic study in orthodox mathematical circles, and the work of preparing the book in the face of obstacles, partly arising from opposition, had proved such a strain that any further discussions on the subject would have been incompatible with my academic duties.

It was this difficulty which rendered it impossible to effect co-ordination with Mr. Bairstow at the time he was engaged in the experimental work required to unite theory with practice.

The result of this want of co-ordination has been that the researches published by the National Physical Laboratory are referred to systems of co-ordinate axes which, apart from all questions of priority, are open to serious objections.

The object of the present paper is to give publicity to the hitherto unpublished arguments which were considered when "Stability in Aviation" was in the course of preparation.

In regard to the selection of which axes to choose for x, y and z, the two-dimensional character of the longitudinal motion of a symmetrical aeroplane leaves us no choice in the matter as the plane of (x, y) is universally adopted as the plane of reference in practically every existing text book on the mathematics, pure or applied, of two-dimensional space. Moreover, "Stability in Aviation" was not the first publication in which this convention was applied to aeronautical problems; in the original Bryan and Williams' papers on longitudinal stability the motions were assumed to take place in the plane of (x, y).

Having settled this point, the axis of z becomes the lateral axis and it remains to decide, with regard to the axes of x and y, which axis is to coincide with the horizontal and which with the vertical direction in a condition of uniform horizontal flight.

As the axes are fixed in the body and the longitudinal velocity is the most important component, the most natural choice is to take this as the direction of the axis of x and the normal direction as axis of y.

The next question to decide is which is to be taken as the positive and which the negative direction in the case of the axes of x and y. The choice for the third axis will depend on whether we wish to use a right-handed or left-handed system. Both systems have been employed in the earlier treatises on mathematics, but in more recent ones the right-handed system has been rendered necessary by electrical

applications, and in aeronautical problems the airscrew constitutes a deciding factor.

If we measure the positive direction of the axis of x backwards the velocity of the aeroplane will naturally be negative, and it is rather amusing to see in the reports of the Advisory Committee velocities quoted as minus 50 miles an hour, or again, minus 88ft. per second, suggesting that the aeroplane was like the mythical "sooner bird," which flies backwards to keep the dust out of its eyes. Moreover, it is not usual to represent velocities by negative quantities except in the case of motions which are acting in a sense contrary to what is usual.

I imagine that this inconvenient notation arose in connection with wind tunnel experiments, but even here there is considerable precedent for treating the direction of the source of wind as the standard or positive direction.

For example, we speak of a north wind when the wind is blowing *from* the north, not towards it.

Now in the case of an aeroplane the two components of resistance, lift and drag, act, one in the opposite sense to that of motion, the other in the upward direction supporting the weight. It would be very inconvenient to have one acting in the positive and the other in the negative sense relative to the corresponding axes. This decides that the axis of y shall be drawn downwards, not upwards. Gravity thus acts in the positive direction of the axis of y.

The only important departures from conventions which have become stereotyped by long continued usage are in the choice of the angular displacements represented by θ, ϕ, ψ, and in the use of the letters X, Y, Z, L, M, N, with and without suffixes to denote resistances acting in a sense opposite to that of the corresponding velocities.

As regards the angles it would have been more logical and conducive to symmetry if we had used θ to denote a rotation about the x axis (or a roll), ϕ one about the y axis (or a yaw), and ψ one about the z axis (or a pitch). But the objection on this ground applies equally to the Eulerian angles of rigid dynamics, and these angles are inapplicable to the small oscillations of an aeroplane or indeed of any rigid body oscillating in three dimensions about a state of equilibrium at rest or in steady motion. Still a change of notation in this case might not be open to objection, apart from the fact that any change causes confusion. On the other hand θ is a much more convenient symbol for inclination to the horizon than ϕ, and this was my deciding factor.

With regard to the convention respecting the components of resistance, the objection does not apply to the actual fact that we represent passive resistances and their coefficients by positive quantities, but rather to the choice of the letters X, Y, Z, L, M, N, to represent resistances instead of positive force components. The use of positive expressions to denote resistances and their coefficients is quite in accordance with previous usages, and to take a somewhat analogous problem we use a positive coefficient μ in the problem of harmonic motion in

$$\frac{d^2x}{dt^2} = -\mu x$$

instead of writing the equation (with μ itself a minus quantity)

$$\frac{d^2x}{dt^2} = \mu x$$

and the solution in the form

$$x = A \cos t\sqrt{(-\mu)} + B \sin t\sqrt{(-\mu)}$$

and the period as $2\pi/\sqrt{(-\mu)}$.

But it would perhaps have been better if we had avoided the use of the letters X, Y, Z, L, M, N. It was and still is difficult to see what other letters of the alphabet could then have been found available for the purpose unless we had chosen double-barrelled symbols like R_x, R_y, R_z, for the force, and G_x, G_y, G_z, for the couple components. But when it became necessary to sub-divide these into so-called derivatives corresponding to the velocity components we might have been stranded in a treble-barrelled notation.

I understand from Mr. Brodetsky that he is proposing a change of notation in this connection, which will leave the letters X, Y, Z, L, M, N, available for representing forces and couples actually *impressed* on the aeroplane as distinct from those due to air resistance. Such a change is, in my opinion, desirable if we can get a good substitute. The great advantage of using positive instead of negative symbols to denote the components of resistance is that when all the terms are brought to the same side in the equations of motion previously to writing down the eliminant in the form of a determinant the number of minus signs in the equations is greatly reduced.

In some recent researches we have found it necessary to make use of data supplied by the reports of the Advisory Committee, and we find that whenever any substantial mathematical work has to be done the confusion of minus signs is most bewildering and it is almost impossible to avoid mistakes, the consequences of which may be serious. The kind of thing which arises is that sometimes a minus quantity has a minus sign standing in front of it and is contained in a bracket which is also prefixed by a minus sign. The algebraical work necessarily associated with aeronautical problems has been the chief obstacle which has hitherto prevented me from interesting myself in aviation to the extent which I should wish, and the mathematical difficulties are far too great already without introducing these unnecessary further complications.

Questions of notation are usually decided by considerations of priority, and on this ground the notation of " Stability in Aviation " possesses the prior claim. Had Mr. Bairstow proposed any alternative system possessing obvious advantages over mine I should have been glad to waive all claims of priority and adopt his changes. But where the proposed systems are open to such serious objections their use by anyone except Mr. Bairstow is calculated materially to retard progress in theoretical aeronautics.

Fortunately, however, such symbols as x, y, z, are rarely needed in descriptions of experimental results, and it is greatly conducive to clearness when algebraic quantities are avoided and results are stated in words. Mr. Bairstow's nomenclature of longitudinal, normal, lateral, rolling, yawing, pitching, is as good as his notation is bad. Further, it lends itself well to suitable abbreviations, some of which were suggested by me in a letter to " Nature." Thus, the components of linear and angular velocity may conveniently be denoted by lo, no, la, ro, ya, pi; the corresponding forces and couples by the use of capital letters as Lo, No, La, Ro, Ya, Pi; and resistance derivatives by corresponding words such as Lolo, Lono, Nolo, and so forth.

This system was adopted by me last spring in two lectures at the Royal Institution and it completely obviates all possible ambiguities arising from notation. It has the further advantage that it fits in equally well with the experimental work of Mr. Bairstow, who proposed such a nomenclature, and with investigations of a purely mathematical character such as are found in " Stability in Aviation."

THE JUVENILE LECTURE.

On Wednesday, January 2nd, Dr. A. P. Thurston, R.F.C., lectured to the children of members and friends of the Society at the Grafton Galleries on "The Aeroplane," the chair being taken at three o'clock by Lieutenant-Colonel O'Gorman, C.B. There was an audience of between five and six hundred.

The lecture was illustrated by models, lantern slides, cinematograph films and experiments, and was greatly enjoyed by everyone. The Council desire to thank Captain Maddick, of the Scala Theatre, Messrs. Pathé Frère, Messrs. Handley Page, Ltd., Messrs. Calthorps, Ltd., Mr. Smith Woodward, of the Natural History Museum, and Dr. R. Mullineux Walmsley, of the Northampton Polytechnic, for the very great kindness shown in the loan of exhibits and direct personal assistance, and to Mr. Edwards, of the Northampton Polytechnic, who had made all the models and assisted with the experiments.

Dr. THURSTON said: I have had many things since the war began, from dodging Hun cruisers in the Caribbean to cruising over dodging Huns in the Channel, but the most pleasant work I have undertaken is the one I have this afternoon. I suppose they have chosen me for this business because they think I and my audience will understand and like one another.

Would you like to be perched up ever so high in the sky and to have a game of geography trying to give names to towns and rivers, islands and estuaries, mountains and lakes, moorlands and forests, hamlets and commons, roads and railways, as they stretch out over the living map beneath? I do. Sometimes a great white cloud, as pure and white as the summit of a snow mountain at twilight, rolls across the landscape, forming a white island fringed with a tenuous fairy iridescence in the midst of an emerald sea; sometimes the clouds come in thousands and shut off the earth completely leaving you alone in the great lone land, an arctic world of endless snow fields broken by great crevasses, winding canyons and mighty caverns, a land of fairy cities with "cloud capped towers, gorgeous palaces and solemn temples" of purest white. Sometimes your machine bowls over the edge of a tremendous precipice of cloud, 10,000 feet high, and you have all the sensation of great height. In the old days one's idea of loneliness was to steer your ship in an arctic sea along blue strips of water between mighty icebergs hundreds of feet high; it is far more lonely to steer your tiny machine through blue strips of sky between mighty walls of iceberg clouds, thousands of feet above and below you. Sometimes as you run over the edge of thunder clouds great sparks 18 inches long form a continuous line along the front edges of the wings.

Do you know where the rainbow ends? I do. I have been there. The rainbow ends on the top of every cloud. When you are above the clouds you sometimes see the rainbow a complete and beautiful circle, sometimes in two circles, one outside the other, and wherever you go above the clouds a halo encircles the shadow of your machine. The flying machine above the clouds is a sacred thing and nature pays her constant tribute of homage to her. I have charged this halo like Don Quixote charging the windmill, it grows smaller and smaller as you approach it and becomes a ball of fire, then you plunge into the cold clammy mist forming the cloud and you are where the rainbow ends.

Birds.

Birds fly by flapping their wings. It won't be any use you trying to fly when you get home to-night by standing on the bedrail in your nightshirts and flapping

your hands; you can't fly because you are not strong enough and your hands are not large enough. The wings of all flying creatures have been formed by the arms and the hands. In birds the second finger has grown so large that it forms the outer portion of the wing, and the thumb and other fingers have grown so small that they have disappeared inside the flesh of the second finger. In bats the second, third, fourth and fifth fingers have grown so very large that a skin stretched between them and the thumb has been left outside the wing. In the pterydactyl, a monster flying reptile that lived hundreds of thousands of years ago, the fifth finger grew so large that it became larger than all the rest of the arm and the hand put together and three fingers were left outside the edge of the wing.

Flying Machines.

Flying machines are men's imitations of the birds. Aeroplanes are birds which rest on the earth and seaplanes are birds which rest on the sea. Aeroplanes are mounted on wheels for running easily over the ground and seaplanes are mounted on hulls or floats for skimming easily over the surface of the sea. When an aeroplane is well piloted it is difficult to tell the exact moment of leaving or restriking the ground, but it is quite different with a seaplane. The waves strike the hull of a seaplane thundering blows which sting the bottom of your feet and each wave tries to throw the nose of the machine into the water.

The slowest aeroplane is faster than the fastest bird. Sometimes when flying in England you may run across a flock of geese flying in arrow formation at 6,000 or 7,000 feet. When they see you they will put their noses down and attempt to dive. Finding that you can dive faster than they can they will flatten out and fly level. A flock of geese going at full tilt can do about 70 m.p.h.

Sometimes in Scotland or in Mesopotamia one runs across an eagle as high as 10,000 or 12,000 feet. It is quite good sport to manœuvre a position so as to photograph the eagle in its native element, but whether it is chasing crows, geese or eagles, they all seem very slow compared with the speed of a flying machine.

How an Aeroplane Flies.

An aeroplane is like a kite which is pulled along by a piece of string. An aeroplane is pulled along by an airscrew turned by a powerful motor. An airscrew is like any other kind of screw which winds itself forward when it is twisted round just like a corkscrew in a cork. This is shown by these flying models.

How Balance is Obtained.

An aeroplane cannot fly unless it is well balanced. If the weight is too far forward it is "nose heavy," if the weight is too far back the machine is "tail heavy." I can show what I mean by means of these three envelopes. The first is an ordinary envelope, but it won't fly. The second envelope is heavily weighted with pennies on the front edge. It also won't fly, but plunges straight to earth. This envelope is nose heavy. If the second envelope had put more of its money into War Loan it would have had a better chance of flying. If I put all of its money into War Loan, except a halfpenny for itself you will find that it flies quite well. Almost anything can be made to fly if it is balanced correctly. Even a boy could be made to fly if he were correctly balanced. I will show you where a boy's wings would have to be if he wanted to fly and then I will show you a small model of a boy fitted with wings at the correct position and you will see the model boy fly.

Control.

A flying machine is controlled by three small surfaces at its three corners. The small surfaces on the wings are called wing flaps and the small surface on the tail is called the elevator. This method of control is like a three-legged stool.

The surface of the stool may be kept level by pushing up which ever leg is lowest. In addition a flying machine is steered by a vertical rudder.

How Man Learned to Fly.

Man learned to fly by first learning to glide as you saw the model. Two American brothers named Orville and Wilbur Wright used to spend their summer holidays practising gliding with box kites which they had built during the winter. When they were quite expert in steering and controlling these kites they put in a motor and made the very first successful flying machine.

Types of Aeroplanes.

There are many different types of aeroplanes now just as there are many different types of birds. They have all been nicknamed; one type is called the Camel, I suppose because it gives the Huns the hump; another the Kitten, because it looks innocent and purrs when it sees a Hun; another the Pup; another the Baby. Officially these machines are known by other names.

(1) *Artillery spotters and photographic machines* have the job of telling the guns where to fire and taking photographs of the Hun trenches and gun positions.

A Scotchman, named Sandy, in one of our squadrons across the water used to fly one of these artillery observation machines. He had a remarkable habit of flying extremely low above the Hun trenches and his friends explained that his reason for flying so low was that he had once dropped sixpence in the Hun trenches and was looking for it. One day Sandy was wounded in the legs three times, he finished his job and landed his machine safely. He fainted on being lifted out of the machine, but when coming to he kept saying, "The pity of it. The pity of it." "Why?" they asked. "I am thinking," said he, "I am thinking I have spoiled ma breeks."

(2) *Long range reconnaissance fighters* have the job of carrying out offensive patrols and observations a long way behind the Hun trenches. They look for trouble and generally find it. These machines are extremely fast and when in full flight the rush of air is extraordinary. One soon becomes accustomed to the noise of the engine, but one never becomes accustomed to the tremendous rush and pressure of the air. One day when flying in one of these machines the speaking tube went wrong and I was unable to communicate with my pilot. The usual means of communication between pilot and passenger is one's boot; it is very effective, but in this case I couldn't reach, so I tried my walking stick. I tried to hold it straight out in front of me so as to touch him, but the rush of air was so great that I was unable to hold it. The stick almost bent and wrenched itself round.

A politician was once given a flight at Brooklands. He opened his mouth in the middle of the flight, so the story goes, and he has not been able to close it since.

(3) *Bombers* have the job of delivering eggs, which they carry on their wings or in their bodies, at Hun railway junctions, ammunition dumps, gun positions, etc. I have brought some of these eggs with me to-day. They are of all weights and sizes, the largest one here weighs 400lbs. We have larger bombs, but they were too heavy to bring.

(4) *Scouts* are the aristocrats of the air. They are small, high-speed, quick-climbing machines, which roll, loop, twist, and turn in a marvellous fashion. Captain Ball flew this type of machine. He spent his leisure practising the art of approaching an enemy unobserved. It is related that on one occasion he was reprimanded by his Commanding Officer for absenting himself from his squadron a short time after leaving the aerodrome and only returned a short time before landing again. He explained that he had been practising the art of concealment

and during the whole flight he had never been more than 200 yards from the tail of his commander's machine.

Description of Flying.

Let us imagine we are going to fly together. We climb into our places, strap ourselves in, sometimes. The mechanic faces the propeller and says, "Contact, sir." You switch on and reply, "Contact." The propeller turns, the engine roars, you wave the signal for the mechanics to pull away the chocks from under the wheels and the machine rushes forward and climbs steeply into the air. You climb so steeply that as you look back you see the earth underneath you and when you look forward you only see the sky. Soon the clouds are reached and a great feeling of freedom and of triumph fills you. I wish I could describe this feeling. When we are glad we clap our hands, we dance with our feet to express a dance of the mind, and we fly to express the immortality of the spirit and the joy of freedom. Cody was once asked if he feared a fall. "Well, boys," he replied, "if I do, when you have picked up the pieces you can write on my tombstone, 'Here lies the body of S. F. Cody, but his heart's in the Highlands.'" Flying is like homesickness; it leaves a pleading, haunting, yearning, which begs, implores and compels until it has had its way. Here is a jolly little cloud, let's jump it; now we are on top, bowling along its surface, and it looks like a white island in an emerald sea. The mosaic of the brown and green fields of Essex roll away beneath, over there are the Chingford reservoirs, on that side is the olive green of Epping Forest with the Connaught waters and the Royal Forest Hotel, that blotch ahead is Brentwood and the next blotch beyond Chelmsford, and the long line between is the Great Eastern Railway. Now we are over Colchester on its silver winding river and it looks as if it is on an arm of the sea. That tiny square of green is Colchester Castle and its quadrangle. A great portion of the Thames estuary stretches away on the starboard side. In front is Mersey Island where the Zeppelin was brought down intact. The Hun commander thought he was over the sea and threw overboard all his secret documents and his gold watch by mistake. We found them all and had the pleasure of handing back his gold watch and listening to his remarks. On another raid the gondola of one of the Zeppelins was blown off and the Zeppelin drifted back to Germany with all the crew, very cold and miserable, sitting in a line on the top like sparrows on a telegraph wire.

Flight Across London.

One day I flew across London. We started in the south, flew over the Isle of Wight and the silver Solent dotted with tiny vessels, then across the purple patch of Hindhead studded around with ponds like deep blue jewels in a purple setting. Sunshine and shadow chased each other over the mosaic of the landscape. Godalming, Guildford, and Windsor great forest roll underneath, and then the silver winding Thames comes into view with London under a mantle of clouds. When I was a boy at school I belonged to the Cadet Corps. One year we camped in a field of snakes; there were snakes in our tents at night and in our marquees during the day. I caught one the first day; it had a great hump in its middle and when we cut it open we found it had swallowed a frog. The Thames winds and turns in an extraordinary fashion before reaching London and from two or three miles above looks like a silver snake which has swallowed a frog and is having a bad time. By-the-by, one of my gloves blew off when over London. Did any of you find it? During the summer London is fairly clear and it is possible to see a great deal of it at once, but during the winter it is under a pall of cloud and smoke, which limits the view to a small portion. It is usually possible to see all the country round London beyond the pall of smoke and cloud. When I last flew over London it was impossible to see any of it except the suburbs of Islington and Hounslow, but across the pall of clouds on the starboard side

the Crystal Palace caught the sun's rays like a building of burning gold and the long line of the North Downs stretched along the landscape; on the port side the Welsh Harp looked like a big black double-pronged radish.

The sentinel balloons which guard London night and day like watchdogs were silhouetted here and there against the white of the clouds. When a Hun appears these balloons send a warning down their telephone wires to the General sitting at the bottom; he sends the warning along to another General in the War Office, who sends out an air warning. Have you ever seen a hen with its chickens; when a hawk appears it makes a funny noise something like a policeman's whistle, spreads out its wings and all the little chickens run underneath and make themselves comfortable. The hawk gets very angry and red in the face and clutches its claws and snaps its beak, but it is unable to do anything except drop dirt. Immediately an air warning is received the Flying Corps spreads its wings over London; you cannot see them, but they are there. Everybody should take cover and have a jolly time. By-the-by, you will invite me to your cellar the next time I am off duty on an air raid, won't you?

I will now show you how we set fire to a Zeppelin, and it is worth noting that we could set fire to a Zeppelin even if it was not full of highly inflammable gas.

(Experiment with Zeppelin and flying model.)

Description of Scotland in Flying.

Flying has opened another world to our imagination. Country beautiful from the ground is often uninteresting in the air. Clouds are usually much more real and form much more conspicuous objects in a landscape than the earth. The chief beauty of the earth seen from above consists in the outline of lakes and mountains, estuaries and rivers, islands and forests. Country untouched by man is much more beautiful than agricultural country. I should like to take the President of the Royal Academy aloft one day and show him what an awful patchwork we have made of the old country and how our railways and towns look like scars upon the face of nature. I once flew over the Grampians and along the coast of Scotland in winter. It was a wonderful experience. The mountains were covered with a mantle of the purest snow which caught the sun's rays and crowned the mountains with blazing gold, shining like the sun in splendour. The lochs were silver jewels in an emerald setting, and emerald land and silver sea embraced each other with many arms. The clouds roll up and we climb above them, passing from the splendour of earth into the glory of cloudland. If you will know the secret of Scotch patriotism, fly over Scotland and you will understand; if you will understand the secret of Welsh devotion, fly over Wales and you will know; if you would understand the beauty of England, fly over England's gardens and you will see. We are told at school that Great Britain is an island, but you soon discover that when you fly. It is not possible to go aloft in any part of England on a clear day without seeing the sea somewhere. If you go up 18,000 feet at Farnborough it is possible to see from the mouth of the Thames to the Bristol Channel with all the lines of the south coast. If you go up only 6,000 feet at Newcastle you can see from shore to shore.

Description of Looping.

The most popular evolution, though by no means the most difficult or alarming, is looping the loop. Suppose we are going to loop together. Now everyone strap himself in and hold on tight to the bottom of your seats. Underneath the earth looks like a great disc and above are the clouds and the sun. Now we are going to loop, hold tight. We push forward the joystick and point the nose of the machine downwards, the horizon in front appears to travel downwards and we look down into the earth with its silver streams, scattered towns and villages and its network of roads and hedges. We gather speed, the wind

shrieks and whistles to the thunder of the engine, we pull the joystick upwards, we feel very heavy, it is difficult to lift your arms and your legs, the horizon rolls downwards and pulls the sky with it. You begin to feel light, you could jump over the moon, you look over the side of the machine and deep down underneath, miles upon miles underneath are the clouds and the sun. We are sitting on the sun; we look above and there is the earth where the sky ought to be and all the little boys and girls, trams and trains, the houses and the churches are upside down and hanging from the ceiling. Our loop continues; the sky travels downwards, underneath the earth becomes a vertical wall in front and the sky a vertical wall behind, we begin to feel heavy again, the earth rolls quickly underneath, the horizon comes back to its original place and the loop is finished. I have looped over battleships, over Stonehenge, over great works and silent lanes, over cathedral cities, just for the very joy of life.

One notices such trivial things when looping; there is a little dog running in front of that tram, there is a motor car coming up swiftly behind; if that little dog does not look out he will be run over. We complete our loop, the motor is astride the road, the tram has stopped and the little dog is limping. The language is evidently painful; one chuckles and flies on. Once when flying over a line of lorries we sounded the Claxton horn, they all went over automatically to the left-hand side of the road and we flew overhead.

The Importance of Flying.

It is quite a mistake to imagine the Huns are great inventors. They are not. They are good imitators, but not great inventors. It is true the sausage balloon which drops bombs on women and children is a Hun invention, but this was invented, I am told, by a German professor one morning at breakfast. The German machines, type for type, are inferior to ours. Our machines fly faster, climb better, and manœuvre more quickly. The great decision of this war will be obtained in the air. If we have a sufficient number of machines it will be impossible for the Huns to surprise us and we can keep their machines away until we have prepared surprises for them. The war has become largely a race in manufacturing power and there is no doubt that we can win.

What we want are more aeroplanes and still more aeroplanes and yet more aeroplanes. Everybody should be at work building aeroplanes; engineers engineering aeroplanes, painters painting aeroplanes, piano tuners tuning aeroplanes, countesses counting aeroplanes, that is the way to win the war.

I have often thought when I have been flying lately, here am I in an aeroplane two or three miles above the earth, overlooking the Channel; what shall I tell the children at Christmas? An hour ago I was in London among all the people, now I am alone among the clouds overlooking the Channel, the earth is dim and shadowy and only the clouds are real. Under the shadow of the wings of my machine is England and all the little boys and girls I love. One feels half an angel in the glory of one's position. Over there across the Channel, where I am looking now, the Armada anchored and Drake came in the darkness of the night with his little ships, his contemptible little ships, and ran in among them and scattered them for ever. On those hills over there Napoleon gathered his great army for the invasion of England. Underneath one can trace the tiny circles of the Martello towers built by our great-grandfathers to resist Napoleon. Napoleon and the Armada have disappeared, England remains. Beyond those hills, an ugly scar across the face of nature, the thundering line of battle stands and a crueller tyrant and a graver menace than Napoleon or Philip threatens. What Drake's ships were to England many years ago the flying machine is to England to-day. The flying machine will be the decisive factor in the war. When the war is over and victory is won the flying machine will change our customs as completely as the railway train changed the customs of our grandfathers. Tell the children of all the glorious places there are on the earth that you have seen

and that will be so much easier to visit by an aeroplane. Jerusalem the golden; the bonny, bonny banks of Loch Lomond, where me and my true love will never meet again; the island paradises of the west with air as fragrant as the Garden of Eden, where the sea breaks on golden sands, where cocoanut trees wave in the breeze, where luscious fruits grow and smiling little black babies live; tell them of the solemn temples of ancient Greece and of the wonders of Egypt and India, and they will know and understand that it is their duty to help to develop the flying machine.

Colonel O'GORMAN voiced the thanks of the audience to Dr. Thurston for his fascinating lecture.

Dr. THURSTON replied.

FOURTH MEETING, 53rd SESSION.

The fourth meeting of the Session was held at the Royal Society of Arts on Wednesday, January 16th, 1918, at 8.0. Lieutenant-Colonel Sir Henry Fowler, K.B.E., Assistant Director General of Aircraft Production to the Ministry of Munitions, occupied the chair.

The CHAIRMAN, in introducing the lecturer, observed that he had heard many excellent scientific papers under the auspices of the Society. To-night they were to have a paper on production, and he personally welcomed it as a subject in which he had a very great interest.

Mr. R. BORLASE MATTHEWS read a paper on "The Use of Jigs and Fixtures in Aeroplane Manufacture."

Lieutenant A. R. LOW, R.N.V.R., who opened the discussion, said it was only recently that they had become an engineering institution. In their papers there was formerly no technical matter peculiar to aeroplane theory. The introduction of papers like the present one was a highly significant departure. By permission of the Superintendent of the Drawing Office, he showed slides depicting the processes of seaplane boat building by the aid of jigs.

Mr. H. R. HOLLIS showed a slide giving an idea of the method of final erection. This had been slightly accentuated in the United States by the adoption of so-called erection jacks, which made the final erection much easier and obviated the use of plumb lines and temporarily rigged means of locating the various points. The erection jig illustrated had been used with much success by the Curtiss Company and had reduced labour by some fifty man-hours per machine, and so increased the output. These jigs accelerated the production of aeroplanes by 75 per cent., and the straining of landing and flying wires had been reduced more to a science than hitherto by the use of tension gauges. He thought the system shown might with advantage be adopted by more manufacturers in this country. The particular jig illustrated was made from gas piping, and called for no great accuracy, because the trays which carried the wings were adjustable. The total cost of the jig was about something under £100. Its U.S. number was Curtiss DX. The saving of labour on one machine more than paid for its share of the cost of the whole jig.

Captain OUTRAM, R.F.C., said, as an inspector, he supposed he would be expected to be prejudiced in favour of the most elaborate jigging possible, because most certainly the more jigging that was done, the easier the inspector's job. The jigs made in different works on much the same lines differed considerably in detail construction, and often in dimensions, and did not take into account the fact that certain tolerances had to be allowed on the detailed parts. That was an argument in favour of Mr. Borlase Matthews's proposal that drawings of these jigs should be considered as carefully as the drawings of the parts. The jigs being designed with various clamps, there was a great tendency to spring the parts into place and the finished part had sometimes lost truth owing to that.

With regard to the necessity for the checking of jigs, jigs were frequently made of soft wood, and the result was a considerable amount of wear and of moving and warping of the jig, and they required constant checking to maintain them in truth. In one case he could not understand why certain ribs came out different from the drawings, and he found that a man had made a part wrongly

and another workman had altered the jig to suit the wrong part. There seemed to be an impression that if a complete component were made in a jig it would be correct in its finished state. That was a fallacy. If a wing were got correctly out of the jig, and covered badly, with too big a strain on it, it was pulled out of truth at once. One had to be very careful, therefore, in deciding at what stage to jig and in watching the effect. He had known elaborate jigs to be made which did not locate the important points of the component. A case occurred recently where with an accurate jig for the fuselage, no attempt was made to locate the fittings for attaching the wings. The fuselage was true, but the wings were out of truth. That pointed to Mr. Borlase Matthews's proposal that the jigs should be carefully designed by a special drawing office. In the majority of cases jigs had to be made up, and one could sometimes make the part he required more quickly than he could obtain certain material for the jig. In the design of jigs he thought only the essential parts should be shown, the details being left to the man who made the jig.

Lieutenant MANN, R.F.C., said the main difficulty they had encountered in checking jigs of a large size was the shortage of accurate measuring appliances. They had experimented with steel rules and tapes, but found them unsatisfactory for gauge and jig making. They set to work to get out a cheap form of gauge, so that they could be loaned to contractors to check their workshop gauges. He showed on the screen the first attempt, which consisted of piano wire stretched from end to end of a frame with discs sweated into position upon the wires. He next showed the present form of gauge, which consisted of a timber frame of cruciform section having sheet metal ends, between which the gauging wire was strained. This frame would carry any one of the gauges, the total of which formed the set for the machine. The wire was $\frac{1}{4}$in. diameter high tensile steel, and the discs were made on a capstan lathe and faced up in a precision lathe, and were slipped on to the wire and sweated up into position. He next showed an appliance they were adopting for assisting in eliminating the complete erection of machines. Doing away with any work increased production, and by avoiding the erection of wings they saved floor space which could be used for other purposes. There had been a lot of difference of opinion as to limits and what clearances were necessary. He showed a table giving information in regard to these matters, and to hinges used in various components.

Captain S. W. HISCOCKS, R.F.C., said if a machine had to be turned out in a week it was impossible to make all the parts to jig. The fault in some of the jigs that had been shown seemed to be due to the original design of the machines. The jigs seemed too elaborate considering the cost of the parts involved. His experience was that the majority of those who had gone into the aeroplane designing business had not the faintest idea how the parts were made or assembled, though there were a few exceptions. There was no need to have a machine for making struts. It could be done on an ordinary spindle.

He would say further that the question of the number of jigs that could be made for production purposes did not depend so much on the production side as upon the people who were responsible for getting out the designs and placing orders for machines.

In many cases the manufacturers are asked to start delivering machines before the drawings are completed, and to do this a large number of parts have to be made by hand from rough sketches, so as to get the production going during the time required to make the necessary tools and jigs for producing parts.

If the country wants cheap production of aeroplanes, it will be necessary to allow some two or three months between the completion of the design and the delivery of the first aeroplane to that design, to enable the manufacturers to lay the work out properly.

Another difficulty in connection with arranging for the use of jigs is that the design of a number of the parts is such that cheap production and assembly by use of simple jigs is impossible, especially so as many of the drawings do not include the necessary limits to ensure interchangeability.

This, he thought, was due to the fact that the aeronautical industry, from a manufacturing point of view, was only about three years old, and that the draughtsmen who prepared the drawings had not had shop experience in the manufacture of aeroplanes.

As an example of the above, one of the photographs shown by the lecturer illustrated a strut copying lathe, which to his mind was an unnecessary machine, as it was quite easy to design struts so that they could be finished, with the exception of cutting to length, direct from the ordinary common spindle, thus cutting out the use of an expensive machine and saving time in production.

Mr. H. PEARMAN said it was the same now as in the early motor car days as regarded the deplorable difference in the amount a firm would spend on plant and that which they would spend on so-called non-productive equipment, and the result was inefficient production. The lecturer's suggestion with regard to the centralisation of jig and tool fixture design was a good one, particularly in view of the control manufacturers were now under. Manufacturers would appreciate the establishing of the principles of the design in a central office, and they would be broad-minded enough to accept such designs in a proper spirit, and greater efficiency would result. A person spending £500 on a machine should be willing to spend £20 on equipment.

Mr. F. HANDLEY PAGE said he thought the Services required a little tuition, and not the manufacturers only. There could not be standardisation of production unless there were unity of demand. Large numbers of machines could not be turned out if changes were made every week. There was a great difference between manufacturing for a Service and manufacturing for a public. In the latter case the public could be persuaded that they wanted what one had to offer, and then thousands or hundreds of thousands of the article could be produced, but it was difficult to persuade a Service, who interrupted the manufacturer frequently with fresh modifications. It was therefore to the Service side that an appeal for unity of demand had to be made. Mr. Borlase Matthews said there were very few jig and tool drawings in this country. He thought the country was hardly so uncivilised as that would indicate. He thought in all decent works there were as many jig and tool drawing offices as ordinary drawing offices. In the case of larger machines than those shown on the slides the question of dividing the machine into units which could be easily assembled separately was of vital importance. It was impossible to have a machine with 100ft. planes completely erected. In the case of his works the planes and other large parts were assembled separately from the machine. He would like to ask Mr. Borlase Matthews whether it was practicable to erect all one's planes in a vertical position, instead of the horizontal method of assembly? Had any manufacturers experience of assembling planes in this way?

Captain BISHOP, R.F.C., said he agreed that the drawings of jigs and fixtures should have more time devoted to them than they had. He remembered one case where contractors complained that the tolerances were too small. New drawings were got out giving exceptionally large tolerances. The contractors then complained that they were too large, as parts made to them would not fit their jigs. Where jigs were instituted higher precision work had to be instituted in the preceding operations. With a long run of production erection jigs were worth making, but his people once laid out a jig on those lines, and by the time the jig materialised the aeroplane was finished. Most gauges required a certain tolerance, and that, as well as the tolerance for the parts, should be allowed for in dimensioning up the various machines.

Mr. DAVIDSON said if jigs were designed at the time the machine was being aero-dynamically considered it would be easier for the manufacturer, as alterations and modifications would not come through in the present quantities, and they would be checked when the jigs were being got out. The limits of interchangeability would have to be considered also, so that several matters could be settled at one time. If there were a central office for designing jigs, and the best way of making a certain part were discovered, that way would be standardised and everybody would not have to make experiments.

Mr. PETTIT said a vital matter to consider was the getting of a big output of machines. Mr. Matthews was rather unfortunate in the choice of one slide which showed a fuselage building jig, and in which the longerons were located by blocks placed inside the longerons and the cramping devices came on the outside, the result being that the compression would be up against the wood block rather than against the strut. The designer of the machine could affect the design of the jig in many ways. In the case of a wing section in some designs the spars were set at any angle to suit the particular section of the wing which had been chosen, rather than to adjust the section in the vertical plane for both spars. If the designer thought more about the design of the jig when getting out his designs it would simplify the production of the machine to a great extent.

Mr. GILLINGHAM said he had known wood to contract 1-10th inch in 20ft., and therefore he did not understand how the A.I.D. could expect to get a limit of plus 1 or minus 1. There was a good deal to be said for jigs in certain forms, but wood could not be stopped from shrinking. If the A.I.D. used a little more—should he say practical knowledge—it would facilitate the output of aircraft.

Lieutenant CROSSLEY, R.F.C., said he thought if the foremen in the works and the tool-room foreman worked together more, the jigs obtained would be more effective. Their combined experience would lead to a much better effect. The tool-room drawing office should work more with the shop foremen, and get their experience of faults found in previous tools and jigs.

Mr. SUMNER said centralisation of design rather assumed finality in aeroplane construction, whereas ideas should be encouraged on the part of sub-contractors and others. The discussion rather took the line that the man who designed aeroplanes could also design jigs, but it required a different training and practice. The tool maker, the constructor of the machine, and the man who was going to use it should all confer, and put all points right at the outset rather than wait till later.

Mr. ALTON said he thought most of the aeroplane designers and draughtsmen had come from the automobile industry and tool shops, and knew little of the vagaries of wood, which frequently changed its dimensions 1-10th in. between the wood-working table and the assembling shop. Metal parts were made with tolerances of thousandths of an inch; when used in conjunction with wood they should rather be in tenths of an inch. Metal parts made in thousandths were sometimes sent back for alterations of some tenths to make them fit the wood parts. It was often the faulty design of the metal parts which called for so much alteration in the assembling of the whole machine.

Mr. WINSHIP said, in view of the reduction of the number of skilled hands and the employment of women, cramps would have to be used in jigs with stops to prevent the women cramping the timber up too tightly.

Mr. W. E. JOHN thanked the author for the valuable information he had given that evening. Whilst fully appreciating the value of the use of jigs and fixtures in the manufacture of aeroplanes, he drew attention to a small point in this connection which had not previously been referred to. One of the gentlemen representing the A.I.D. had stated that they advocated the extensive use of jigs and fixtures, since it reduced their work to a large extent owing to the greater accuracy of the parts produced. It must, however, be remembered that jigs and

fixtures are generally used by unskilled labour. An unskilled workman operating an inhuman machine, such as a jig, provided with some of the cramping devices shown on the screen that evening, will lack the "feel" possessed by a skilled craftsman and will not realise what harm he may be doing to some parts he is handling. A man working with wood all his life acquires a sense of touch which will warn him at once if by chance a part is over stressed when he is bending it or even when he is placing it in the jig. The part may perhaps possess some invisible flaw. If he is a conscientious workman he will throw such part aside. If, however, he has not had the experience, without realising there is anything amiss, he will build the part into the machine, and it will take the best inspector all his care to detect the fracture. For this reason, therefore, he wished to point out that with the increasing use of jigs and fixtures more attention must be given to the thorough instruction of the operators using such jigs and fixtures.

The CHAIRMAN (Sir Henry Fowler) said Mr. Matthews had mentioned that to have a machine jigged properly about 1,200 jigs were required. In the present state of the labour market this was a very serious matter. The time would undoubtedly come when constructing machines on a commercial rather than on a war basis, when what Mr. Matthews had demonstrated would grow to a very large and interesting state, and would be one of the most interesting propositions that had ever come before engineers. There was a difficulty at present in getting sufficient jig makers and draughtsmen.

Mr. R. BORLASE MATTHEWS, in reply to the discussion, said that if a factory had a proper jigging system, the jigs succeeding each other became self-jigs, and if a man strained a piece of wood by forcing it through one jig, the false work would probably be discovered when it was fitted in an assembly unit. He did not think inspectors would be out of work by any means if everybody jigged, as the jigs would have to be inspected from time to time on account of wear. He did not mean to say there should necessarily be one universal jig office. That would be too big a scheme with the present shortage of expert jig draughtsmen. Rather he intended to convey the importance of associating a jig designing office with each firm of aeroplane designers. This jig designing department should supply drawings of jigs for all the aeroplanes designed by the firm, to the sub-contractors making each particular machine. The wood-working for aeroplanes had been developed largely by people who had been in the furniture and other wood trades, and they could not be expected to become experts immediately in the aeroplane business. Hence, any assistance that could be rendered in the shape of drawings of jigs should be given, though the designs need not of course be followed in minute detail. Even with the drawings as a basis, there was ample scope for ingenuity and initiative in the construction of the actual jigs. However, at the moment, jig drawings were conspicuous by their absence. He did not intend to despise the skill of the foremen. He meant to say that the main scheme should be laid out on scientific lines before placing the work in the shops, and if the foreman ran short of a special kind of wood or the like, it was up to him to make the necessary modifications, or if he wanted to substitute certain metal fittings for wood, there was no reason why he should not apply the scientific principles that had been laid down. One manufacturer in this country had found it worth while to lay down 5,000 jigs to make one machine, and, as he had pointed out in the paper, the thing was a business proposition.

He knew of a case where the Services decided not to introduce any modifications into a machine, and in a short time they received a couple of hundred modifications from the manufacturer himself. A question to be considered was how long it would be before wood was replaced by metal in aeroplane manufacture.

He had seen vertical jigs for plane manufacture. They were very compact, and constructed entirely of metal.

For wood that had been properly seasoned, either naturally or artificially, he

saw no difficulty in fixing limits, and in working to those limits. American and German manufacturers had devoted greater attention to the manufacture of jigs, than had those in this country, although some of our manufacturers moved with the times.

One outstanding feature of the aeroplane industry was that a very large number of difficult problems had been presented, which have had to be most carefully considered. Incidentally, these problems had brought out much ingenuity in their solution. An example, to which reference had been made in the discussion, was the special type of gauge for measuring lengths, devised by the A.I.D.

CORRESPONDENCE.

To the Editor of the AËRONAUTICAL JOURNAL.

SIR,—Some of the remarks on Mr. Dines' lecture, attributed to me, are rather confusing and inaccurate.

I said that air resistance did not vary as the square of the velocity; that this was well recognised in a certain branch of the National Physical Laboratory; that even as far back as Newton this was known, since we find in the "Principia," "And *when* the resistance of bodies in non-elastic fluids *is once known*, we may then *augment this resistance a little in elastic fluids*, as our air." (Italics added.)

Theory and experiment show that you must add a fraction which is the ratio between the *speed of the motion* and the *speed of flow of the air* (under the conditions of the experiment) *into a vacuum, i.e.*, $(1+s/S)$, where s and S are the two speeds.

Mr. Bairstow's empirical formula, which is the same as Zahm's, and commonly, but (I think) inaccurately, considered to be the same as Duchemin's, is not homogeneous; since the second term bv^3 has not the dimensions of "force."

The statement, attributed to me, that "The resistance should be multiplied by the speed, which complied with the law of dynamical similarity," is therefore incorrectly reported.—Yours faithfully,

R. DE VILLAMIL.

February 9th, 1918.

REVIEWS.

A Dictionary of Aircraft. By W. Erskine Dommett, A.F.Aë.S., M.I.Mar.E., A.M.I.A.E. London. 1918. Electrical Press, Ltd. 52 pp. oct. 2s.

This is a useful little book containing an alphabetical classification of terms used in aeronautics, scientific, popular, colloquial and military. It is to be questioned whether the definition of such general engineering terms as "indicated horse-power," "petrol engine," "laminæ," or "piston," is quite necessary in an aeronautical dictionary. In view of the fact, too, that an attempt is now being made to standardise all aircraft terms, one wonders whether Mr. Dommett's dictionary will long remain authoritative. It is, however, a handy publication and will prove particularly informative for the general reader. On that account the inclusion of terms habitually in use in the popular press in their lucubrations on the air is perhaps to be commended. It should be noted that under the heading "Propeller," Mr. Dommett refers us to "screw, air." "Airscrew" he defines as "a generic term to include both a pusher propeller and a tractor screw," while "screw, air" is defined as an aerofoil. This is prudent and judicial and everybody ought to be pleased. Mr. Dommett finally exhausts the subject with a definition of a "screw propeller." This last is a happy compromise.

An Airman's Outings. By "Contact." Introduction by Major-General W. S. Brancker. London. 1917. Blackwood and Sons. 323 pp. oct. 5s.

This is one of the most fascinating popular books on the air issued in recent years. Very few will read it without the pleasure and benefit which come from the communication of actual experience acquired at first hand. The author shows a vivid power of description which gives conviction to a series of narratives enthralling in themselves. A passage in General Brancker's introduction is worth quoting:—"War has been the making of aviation, let us hope that aviation will be the destruction of war." To that one can say ditto, but after all most inventions are made first for warlike purposes. The greatest inventor who ever lived made the first wheel thousands of years ago. He had in all probability no altruistic intentions. It is most likely, indeed, that he first applied his notion to a war chariot. Whoever he was, however, he made modern civilisation, and must have killed many millions of people. Let us hope that it will not always be necessary to set fire to the home in order to dine off roast pork.

Aircraft in War and Commerce. W. H. Berry. Introduction by Lord Montagu of Beaulieu. Illustrated. London. 1918. E. J. Burrow and Co., Ltd. 1s. 6d. Oct., 146 pp.

This is a handbook in popular form giving a very complete and interesting account of aerial matters now and after the war. There is nothing absolutely novel in the volume, but the author has collected his material with both imagination and discrimination, and the book may be cordially recommended to those who are interested. Those few who are not interested in the air will speedily become so if they will read what Mr. Berry has to say.

"If all men were virtuous, I should with great alacrity teach them all to fly. But what would be the security of the good, if the bad could at pleasure invade them from the sky. Against an army sailing through the clouds, neither walls, nor mountains, nor seas, could afford any security. A flight of northern savages might hover in the wind and light at once with irresistible violence upon the capital of a fruitful region that was rolling under them."—*Dr. Johnson.*